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. . . represents an effort by the Society to deliver technical data direct from the authors to the reader with the greatest possible speed. To this end, it has none of the usual editing required in more formal publications.

Readers are invited to submit discussion applying to current papers. For papers in this journal the final date on which a discussion should reach the Manager of Technical Publications appears in the table of contents and as a footnote with each paper.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Paper" (Proceedings Paper 290). For free copies of this paper—describing style, content, and format—address the Manager, Technical Publications, ASCE.

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JOURNAL

AIR TRANSPORT DIVISION

Proceedings of the American Society of Civil Engineers

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AIR TRANSPORT DIVISION

Proceedings of the American Society of Civil Engineers

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Discussion of
"BASE COURSE AND BITUMINOUS PAVEMENT REQUIREMENTS"

by W. J. Turnbull and O. B. Ray
(Proc. Paper 424)

W. J. TURNBULL[a] and O. B. RAY,[b] MEMBERS, ASCE.—The discussion by Mr. Bauman has been read with interest. The statement in the first paragraph under "Base Course," "However, well-graded gravel, crushed slag limerock, and coral may be used satisfactorily as base course," is apparently responsible for Mr. Bauman's opinion that the writers class slag as a secondary material. It was specifically not the intent of the writers to indicate that the materials mentioned above are secondary to crushed limestone, granite, and trap rock. The intent was simply to show that the latter-named materials are more commonly available for use throughout the country than crushed slag, limerock, and coral.

The writers agree with Mr. Bauman that slag, limerock, coral, and gravel will make good base course materials, although in some instances difficulty has been experienced with well-graded gravels containing very little or no crushed material because CBR values measured after construction were below 80 per cent. The writers again wish to emphasize that the most important criterion of a good base course material is that the fines be nonplastic or have a low plasticity index. Certainly, in no case should the plasticity index of the fines exceed 6 per cent.

The writers further agree with Mr. Bauman that excellent asphaltic concrete can be made from slag materials. However, slag material must be classed as a relatively porous aggregate, and as is the case with all porous aggregates, the proper proportioning of asphaltic cement in the final mixture is more difficult than if the aggregate is nonporous. In order to meet this latter difficulty the Corps of Engineers has developed a bulk impregnated specific gravity. The use of this new type gravity, which is described in ASTM Preprint 92, "An Evaluation of the Specific Gravity of Aggregates for Use in Bituminous Mixtures," has not eliminated all the difficulties in designing asphaltic mixtures using porous aggregates; however, it is an improved approach over those using either bulk or apparent specific gravities as defined by ASTM.

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a. Chief, Soils Div., Waterways Experiment Station, Corps of Engrs., Vicksburg, Miss.
b. Engr., Waterways Experiment Station, Corps of Engrs., Vicksburg, Miss.

Discussion of
"BASE COURSE AND BITUMINOUS PAVEMENT REQUIREMENTS"

by W. J. Turnbull and C. [illegible]
(Proc. Paper 3041)

W. J. TURNBULL,[a] and C. [illegible],[b] MEMBERS, ASCE.—The discussion by Mr. [illegible] has been read with interest. The statement in the third paragraph under "Base Course," "Concrete, well-graded gravel, crushed-slag limestone, and coral may be used satisfactorily as base course," is apparently responsible for Mr. [illegible]'s opinion that the writers place slag in a secondary category. It was specifically not the intent of the writers to indicate that the materials mentioned above are secondary to crushed limestone, granite, and trap rock. The intent was simply to show that the better quality materials are usually commonly available for use throughout the country—i.e., crushed slag, limestone, and coral.

The writers agree with Mr. [illegible] that slag, limestone, coral, and gravel will make good base course materials, although in some instances difficulty has been experienced with well-graded gravels containing very fines in the finished material because of fine materials generated after construction more than 10 per cent. The writers again wish to emphasize that these conditions, the difficulties of a good base course material is that the fines be nonplastic or have a low plasticity index. Certainly, in no case should the plasticity index of the fines exceed 6 per cent.

The writers further agree with Mr. [illegible] that excellent bituminous concrete can be made from slag materials. However, when material usually classed as a relatively porous aggregate, such as is the case with slag [illegible] aggregates, the proper proportioning of materials based on the [illegible] is more difficult than if the aggregate is nonporous. In order to overcome this minor difficulty the Corps of Engineers has developed a test method and specific gravity. The use of this new type gravity value is described in ASTM Preprint 72, "An Evaluation of the Specific Gravity of Aggregates for Use in Bituminous Mixtures." This not eliminated all the difficulties in designing asphaltic concrete using porous aggregates, however, it is an improved approach over those using either bulk or apparent specific gravities as defined by ASTM.

a. Chief, Soils Div., Waterways Experiment Station, Corps of Engrs., Vicksburg, Miss.
b. Asst. [illegible], Waterways Experiment Station, Corps of Engrs., Vicksburg, Miss.

Discussion of
"AIRFIELD PAVEMENT DESIGN OF THE CORPS OF ENGINEERS"

by Gayle McFadden
(Proc. Paper 458)

GRANT S. ANDERSON,[1] M. ASCE.—Figure 6 illustrates the common practice of constructing asphalt concrete pavement in two layers, called the binder or leveling course and wearing course.

Experience at Los Angeles International Airport has been that slippage of the wearing course over the binder course frequently has occurred under heavy airplane wheel loads. As a result, sections of wearing course as large as 400 square feet have torn loose and have had to be replaced. This condition has affected portions of both east-west runways and one taxiway intermittently since the pavements were constructed in 1950.

Repairs made by the Airport maintenance crew have been expensive enough to offset any economy which might have resulted from specifying a binder course less costly than the surface course. In any case, however, interference with airplane traffic is an important matter to be considered as well as the cost of repair.

The Taxiway was constructed in 1950 with a 2-inch binder course and 2-inch surface course. Both east-west runways, in 1950, received an asphalt concrete overlay over the old asphalt pavement. This topping was placed in two layers, the lower varying from 1 to 4 inches in thickness and the upper being 2 inches thick. A tack coat was applied between binder and surface courses on runway 25-R, but not on runway 25-L and the taxiway. Runway 25-L, however, has been almost entirely free of slippage cracks.

The writer observed most of the construction in question and was satisfied that no dirt was tracked or blown onto the binder course before application of the surface course. Careful inspection and testing assured compliance with the specifications, and the work was well performed by experienced contractors.

In 1954 the Asphalt Institute had tests made in an attempt to determine the cause of the trouble. The results were included in a report dated March 30, 1954, prepared by Mr. B. A. Vallerga, Managing Engineer, Pacific Coast Division of The Asphalt Institute.

Nine 4-inch by 4-inch square samples of the pavement from runways 25-R and 25-L were removed with a circular diamond concrete saw. They were taken from areas affected by slippage and from areas unaffected. It was thought that the samples from the trouble spots might be found to have some defect not to be found in the other samples. The test results were a disappointment in this respect, however, as there was no direct correlation between any of the properties measured and the locations from which they were taken. Moreover, the asphalt mixtures used were found to be of good quality.

1. Asst. Airport Engr., Dept. of Airports, City of Los Angeles, Calif.

The properties measured by the Asphalt Institute included water content of subgrade, asphalt content and grading analysis of the pavement, bulk specific gravity, corrected cohesiometer value, and Hveem stability and specific gravity on remolded samples.

No base failures occurred to account for the slippage. Repairs were made by replacing only the 2-inch wearing course. The existing binder course was scarified at right angles to the runway direction and given a tack coat before placing the wearing course patch.

Judging from the locations and nature of the slippage cracks, they resulted from horizontal forces imposed by heavy wheel loads. These in turn were apparently caused by landing impact in the touch-down area and by braking in other areas. It was also apparent that a definite plane surface, caused by rolling, existed between the binder course and wearing course. This surface remained plane and smooth after the slippage cracks widened. In samples cut from the taxiway pavement before slippage occurred, the two courses were found to be tightly bonded together.

The single layer method of construction has since been used in extending the main runways at Los Angeles International Airport. The slippage problem has been eliminated, the new pavement has been as good as the two-layer pavements in all other respects, and the cost of placing the pavement has been less. The importance of being sure that a runway will not be closed for repairs during time of all our war should be sufficient reason for specifying a single-layer wearing surface on military airfield runways.

GAYLE McFADDEN,[2] M. ASCE.—Mr. Anderson's discussion of the relative merits of single vs. multiple course construction of asphaltic concrete pavements has been reviewed with interest. The writer has inspected many thousands of square yards of asphaltic concrete pavements that have been built in two or more courses, and they have been almost universally successful. There have been a few instances where a plane of separation occurred between the binder and wearing course, but these have been isolated cases and an investigation has invariably determined a very definite reason for the occurrence. Outside of the economy of construction, which has been proven by actual contract bids, it is doubtful if the all-important element of density can be successfully built into the pavement, with equipment commonly owned by the average contractor, in one single course of four inches as can be constructed in two courses of two and one-half inches and one and one-half inches. Because of the successful construction of many thousands of square yards of multiple course asphaltic concrete pavements and the obvious advantages of this type construction, I believe that it would be far better to make an exhaustive investigation of the few isolated cases of failure with a view of correction than to make the suggested change in construction method.

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2. Chief, Construction Eng. Section, Bureau of Facilities, U.S. Post Office Dept., Washington, D. C. Formerly Chief, Airfields Branch, Engr. Div. (M.C.), Corps of Engrs., U.S. Dept., of the Army.

Discussion of "THE EFFECT OF TRAFFIC UPON RUNWAY PAVEMENT CROSS-SECTION"

by Robert Horonjeff and John Hugh Jones
(Proc. Paper 720)

ROGER H. WILLIAMS,[1] M. ASCE.—In the nomograph, Fig. 10, page 720-12, it appears that scales B and C for contact pressure and contact area have been plotted incorrectly around the point of 100 psi. contact pressure (e.g., if all factors are held constant except contact pressure and contact area and these are changed to 200 psi. and 250 sq. in. respectively, the thickness of pavement indicated is less than that for 100 psi. and 500 sq. in.).

The overall pavement thickness reduction in the example given amounts to 16.7 percent while the reduction of plant mix is 33.3 percent, of base course is 22.2 percent, and of select material course is 12.5 percent respectively. Since the wearing surface is the key feature in the durability of an otherwise properly designed and constructed pavement, the relatively large reduction of this course in relation to the reduction for the other courses and the overall reduction appears questionable.

The cost of excavating existing subgrade to place the thicker select material in the center section and/or the cost of common fill in the exterior sections should also be included in the cost comparison as should any increase in contractor bidding cost for placing the layers of varying thickness.

J. F. REDUS,[2] A.M. ASCE.—The authors have brought up a rather timely subject and are to be congratulated for a well-conducted study. The volume of airfield construction currently under way calls for the expenditure of large sums of money, and any means of reducing costs without impairing the ability of the pavement to perform its intended function is certainly in order.

The authors mentioned in their discussion that the traffic patterns on military fields might be different from those on civil fields. This discussion deals with traffic distribution on military fields.

The Corps of Engineers through its Waterways Experiment Station conducted a traffic distribution study on military airfields about 1945 which was designed to determine the amount of traffic airfield pavements received so that proportional amounts could be applied to accelerated traffic test sections. This study was summarized in the paper "Design Curves for Single-Wheel Loads" by C. R. Foster which is a part of the symposium "Development of CBR Flexible Pavement Design Method for Airfields," Transactions, Vol. 115, 1950.

To determine the distribution of landings, tire marks were counted in 10-ft lanes across the width of the pavement at several places on each of the 28 fields studied. The runways were 150 ft wide. The fields fell into three

1. Prin. Civ. Engr., Metcalf and Eddy, Cons. Engrs., Boston, Mass.
2. Engr., General Investigation Section, Flexible Pavement Branch, Soils Div., Waterways Experiment Station, Corps of Engrs., U.S. Army, Vicksburg, Miss.

groups according to gross weights of the predominant planes: (a) less than 10,000 lb, (b) about 30,000 lb, and (c) about 60,000 lb. The study showed that the widths of pavement in which 75 per cent of the landings occurred were 85, 75, and 50 ft, respectively, for the three groups. Seventy-five per cent of the traffic occurred in a width of about 40 ft (fig. 9) at the fields observed by the authors. This is believed to compare favorably with the value shown for group (c) planes when it is considered that these were mostly training fields.

Using the above distribution and records of landings and take-offs from control towers, the number of coverages applied to the central portion of a runway was computed by assuming uniform distribution over the central portion. Although the distribution is not exactly uniform, it is near enough so that this assumption can be made. These studies showed that under intensive training conditions, the central portion of the most used runway of a multirunway field generally received about 5000 coverages in a five-year period.

Runway traffic is slightly different on take-off from that on landing. A single plane taking off alone tends to use the central portion of the runway, the width used depending on the type and spacing of the main landing gear. However, take-offs are made on numerous fields with planes in a staggered pattern.

From the foregoing discussion, it can be seen that traffic for military planes with a particular landing gear falls into a rather well-defined pattern. If it could be established that the planes using the field for the life of the pavement will be of a given type and that no widening of the pavements will be necessary, then a nonuniform cross section could be designed which would reflect considerable savings.

Recently guide lines have been painted on taxiways and apron taxilanes to aid pilots in keeping wheels on the pavement and in clearing parked aircraft. The following of these lines has resulted in "channelization" of traffic. Insufficient data are available to include channelized traffic in this discussion.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 861 is identified as 861 (SM1) which indicates that the paper is contained in issue 1 of the Journal of the Soil Mechanics and Foundations Division.

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c. Discussion of several papers, grouped by Divisions.

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